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THE USE OF WOODY MATERIALS ON AGRICULTURAL LAND: A REVIEW

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Attention has been focused recently on the large amounts of woody residues that are available in various parts of the United States (28, 51, 52).[1] Large amounts of sawdust accumulate at sawmills, and proper woodlot and forestry management practices add to the supply of available wood waste materials.

Many of our agricultural soils are badly in need of organic matter. Woody residues should be a good source of soil organic matter, since they contain considerable amounts of lignin or lignin-like components that are highly resistant to the decay action of microorganisms.

Woody materials also contain appreciable quantities of carbohydrates such as cellulose, pentosans, and wood sugars, which furnish energy for the growth and activity of microorganisms. The nitrogen content of woody materials is relatively low in comparison to their energy content. The microorganisms that attack woody materials require nitrogen in order to synthesize proteins for their bodies. Being unable to utilize atmospheric nitrogen, they are forced to draw upon some other source. Consequently, when woody residues are allowed to decompose in soil, a temporary shortage of available nitrogen is likely to occur unless provisions are made to correct the nitrogen deficiency.

The growth of the organisms also requires available phosphorus, and under certain conditions may produce a temporary phosphate deficiency (19).

Wood waste problems are so important in the Northeastern States that the Northeastern Wood Utilization Council has been formed to cope with them. The problems and possible methods of solution are discussed in a bulletin published by the Council (28).

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[1]Figures in parentheses refer to Literature Cited.

Recent articles by McIntyre (24) and Schrack and Albright (33) call attention to developments in machinery for converting the vast stores of wood wastes into chips that may be used on cultivated land. McIntyre points to the need of further research in order to learn how to use these materials to best advantage and without harmful effects to economic plants.

The following is a review of recent work on the effect of woody materials on soils and plant growth. The use of other crop residues and their relationship to soil toxicity has also been reviewed to a limited extent. Although the literature coverage is by no means complete, it may serve to point out some of the real problems involved and to suggest possible methods of solution.

EFFECT OF WOODY RESIDUES ON SOIL NITROGEN AND GROWTH OF HIGHER PLANTS

Baker (1) reported excellent results from using sawdust as a mulch on Indiana apple orchards, provided sufficient available nitrogen was applied during the first few years after application. No evidence of toxic effects was noted. Collison (5) recommended the use of sawdust mulch for orchards, blueberries, and other fruits in New York State. Collison cautions that the addition of lime and a source of nitrogen may be necessary. Latimer and Percival (20) noted retarded tree growth and symptoms of nitrogen deficiency in the foliage of apple trees mulched with sawdust in the absence of fertilizer application. Data presented by Turk and Partridge (48) indicated that nitrate production in a soil mulched with wood shavings or sawdust, although somewhat retarded as compared to unmulched soils, was somewhat greater than where a straw or corn stover mulch was used.

Soderbaum and Barthel (40) found that 2 percent sawdust in soil decreased crop growth. They concluded that the detrimental effects were caused by lack of available nitrogen since normal growth occurred in the presence of sufficient nitrogen. Johnson (18) observed that sawdust mixed with soil depressed the nitrate content. When employed as a mulch, the effect was less the first year than during the following 3 years. Johnson concludes that old pine sawdust can be mixed with soil without injurious effects provided a sufficient amount of nitrogen is added. Turk's results (45, 46, 47) obtained in Michigan over a period of years show that the harmful effects of sawdust on plant growth are the result of a depression of the available soil nitrogen. It was pointed out that plants grown on soils high in nitrogen content did not usually show depressive effects. Well-rotted sawdust did not show detrimental effects. In order to overcome the harmful effects of sawdust, Turk (45)

recommended the addition of sufficient nitrogen to raise the nitrogen content of the sawdust to 2 percent. This would require about 225 lbs. of sodium nitrate or about 180 lbs. of ammonium sulphate per ton of sawdust. Viljoen and Fred (50) attributed the unfavorable action of different kinds of wood on the growth of oats and clover to nitrate deficiency and not to toxicity. Stone (43) also discounts the toxicity theory and says that available nitrogen is the real problem. White (51) has compared the relative merits of sawdust and wheat straw when used as agents for absorbing stable and hen manure. The release of soil nitrates was somewhat greater where sawdust was employed than where straw was used. Boischot and Barbier (3) concede that sawdust is a satisfactory source of soil organic matter but is inferior to straw and because of its slow rate of decomposition requires a longer period of composting before using on croplands.

The following table shows the effect of relatively undecomposed woody residues applied at the rate of 4 tons per acre on the nitrate nitrogen content of soil with and without a tobacco crop:[2]

	Nitrate nitrogen content (ppm) of top 3 feet of soil			
	July		August	
Woody residues	With tobacco	Without tobacco	With tobacco	Without tobacco
Present	4.11	4.97	1.68	7.55
Absent	7.07	9.40	2.21	9.20

The July and August results were obtained approximately 1 and 2 months, respectively, after application of the residues and transplanting the tobacco. The effect of the growing tobacco crop in decreasing the soil nitrates was very small 1 month after transplanting and very pronounced after 2 months. The woody residues decreased the amount of nitrates on both dates with and without a growing tobacco crop.

More recent results show promise of overcoming the nitrogen problem by applying the woody residues in the fall and plowing them under in the spring along with a legume cover crop. This work has not yet progressed to the point where definite conclusion can be drawn.

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[2]Cooperative project with C. S. Britt at the Soil Conservation Service Research Tract, Beltsville, Md.

EFFECT OF WOODY RESIDUES ON THE NITRIFICATION PROCESS

Viljoen and Fred (50) and Turk (45) have presented evidence that the harmful effects of wood residues are a result of the depletion of nitrates by microorganisms after they are formed. The nitrification process apparently was not reduced in efficiency.

FERTILIZER VALUE OF WOODY RESIDUES

Turk (45) has pointed out that sawdust is an inert material and not a true fertilizer. It contains about 4 lbs. of nitrogen, 2 lbs. of phosphorus (P_2O_5) and 4 lbs. of potassium (K_2O) per ton of air-dry material. These elements are mostly in the unavailable form.

Lunt (21) showed that unleached ashes from various kinds of wood have inorganic fertilizer value.

The total quantity of exchangeable bases of a soil was decreased by mulching with sawdust or wood shavings in an experiment reported by Turk and Partridge (48).

Sawdust and wood shavings are proving a good substitute for more expensive straw in the bedding of animals. Midgley (25) has shown that these materials have high absorptive capacities for the soluble nitrogen and potassium that occur in the liquid portion of animal manure. The addition of superphosphate to bedded manure is also recommended.

The rate of decomposition of sawdust alone and with stable or hen manure was shown by White (51) to be less than that of wheat straw. Soil nitrate content was greater where the manures were mixed with sawdust than where wheat straw was used.

WOODY RESIDUES AND SOIL TOXICITY

According to Stone (43) the toxicity and "sour" soil theories are largely without foundation where the use of woody materials are concerned. Apparently, little or no data are available to support such claims.

McCool (23) determined the pH of sawdust from various sources. Values ranging from pH 3.5 for cypress to about 6.0-6.5 for larch, locust, elm, and hemlock were obtained. Pines, oaks, maple, and others

were intermediate. Leaching resulted in increasing the pH values (decreasing the acidity). The addition of sawdust in some cases increased the pH of soil and decreased it in others.

Geesaman and Norris (13) reported the pH of raw oak and pine sawdusts as 4.5 and 5.5 respectively. When used for bedding cattle, the reaction became neutral or alkaline because of the absorption of urine.

Very little change in the pH of soil was shown by Turk and Partridge (48) as a result of mulching with sawdust or wood shavings. The same conclusion was reached by Boller and Stephenson (4) when mulching with fir or alder sawdusts. Mulches of walnut leaves reduced the acidity of the soil within the top 6 inches. The effect was most pronounced within the top 2 inches and diminished with depth. Collison (5) recommends the use of lime to offset any acidity resulting from the use of mulch. Midgley (25) does not believe the use of sawdust causes excess soil acidity.

Midgley (25) reported the production of normal crops on soil to which large amounts of tannin or tannin-containing materials were added and to which proper fertilizers were applied.

SOIL TOXICITY AND FIELD CROP RESIDUES

A number of studies have been made on the presence in soil of organic substances toxic to plants (30, 34, 35, 36, 37, 38, 39). It was postulated by Schreiner and Shorey (37) that many such compounds arise from the decomposition of animal and vegetable matter.

Among the toxic compounds isolated by chemical methods from the soil and identified are dihydroxystearic and picoline carboxylic acid (37).

In experiments with coumarin, vanillin, and quinone, Schreiner and Skinner (39) demonstrated toxic effects on wheat seedlings. By using nitrogenous, phosphatic, and potassic fertilizers, they were able to overcome the toxic effects of vanillin, quinone, and coumarin, respectively.

The destruction by microorganisms of coumarin, vanillin, and of toxic compounds produced by steam sterilization of soils was demonstrated by Robbins (30).

Recent work by McCalla and Duley (22) showed that aqueous extracts of sweetclover had a depressing effect on the germination and growth of corn seedlings. Coumarin, a substance present in sweetclover and other residues, had a similar effect.

Sorghum (7, 15) and wheat straw (6) have been implicated in causing injury to succeeding crops. Conrad (7) believes the injury caused by

sorghum residues to be a result of nitrate depletion, while Hawkins (15) attributed it to effect on soil structure.

Collison and Conn (6) concluded that two factors operate to produce harmful effects on plant growth during the decomposition of wheat straw. One was the competition for available nitrogen and the other the liberation of toxic substances.

MICROBIOLOGY OF WOODY RESIDUE DECOMPOSITION

The most important group of microorganisms that take part in wood decay are the Basidiomycetes, a group of fungi belonging to the mushroom family. Many other organisms, especially the bacteria and fungi that decompose cellulose and other carbohydrates commonly found in wood also play an important role. The activities of certain of the cellulose-decomposing bacteria, however, may be inhibited by the presence of antibiotic substances present in wood (17).

Wood decay frequently begins with forest pathogens which attack, and in many cases, kill the tree. These are followed by saprophytic organisms which live upon the dead material. Many different kinds of organisms may be involved before the woody material is transformed into soil organic matter or humus.

Wood-destroying fungi are commonly divided into two types on the basis of kind of decomposition produced (12). They are known as brown rot and white rot fungi. Brown rot fungi attack cellulose and other carbohydrates but have little effect upon lignin. White rot fungi attack lignin as well as carbohydrates. Most white rot fungi were found by Davidson, Campbell, and Blaisdell (8) to produce a distinctive type of reaction, which they called the "oxidase" reaction, when grown on a medium, first described by Bavendamm (2), containing gallic or tannic acid. The "oxidase" reaction has been used by Nobles (27) as an aid in identifying wood rotting fungi. Common soil fungi, including Fungi Imperfecti and Ascomycetes, that gave the "oxidase" reaction on tannic acid media were shown by Dawson (9) to be more active in decomposing wheat straw than "oxidase negative" fungi.

Nature has amply provided and widely distributed a large variety of wood-rotting organisms. They are present wherever the need for them arises and conditions are favorable for their development. Thom (44) has pointed out that wood waste decays chiefly by the wood-rot organisms it carries with it, and that these are supplemented by rotting

agents that survive in the soil.

Nikolaevskaia and Chastukhin (26) recognized three stages in the decomposition of spruce wood. Wood-coloring fungi which feed on the cell contents predominated during the first stage. These were accompanied by ammonifying bacteria. During the second stage acid-producing basidiomycetes predominated at the expense of the bacteria. The third stage was predominated by Fomes pinicola, which upon death, liberated ammonia causing a rise in pH.

White (51) and Boischot and Barbier (3) showed that sawdust was somewhat more resistant to decomposition than wheat straw.

Decay resistance of wood has been associated in some cases with the presence of water-soluble substances toxic to wood-rotting fungi (32, 41).

Wormold and King (53) recommended the use of weathered wood prunings and sawdust because of the danger of introducing Armillaria mellea, a fungus pathogenic on many trees, shrubs, and vegetables, by the use of fresh woody materials.

DECOMPOSITION OF LIGNIN

Although the lignin component of wood is very resistant to decomposition, a number of microorganisms are capable of attacking it. The various "white rot" fungi, frequently encountered by forest pathologists, form an important group with respect to lignin decomposition. The extent to which the lignin fraction is decomposed varies with the microorganism and with the chemical composition of the wood. Heuser and coworkers (16) demonstrated that by choosing the right combination of wood (aspenwood) and fungus (Polyporous paragamenus) the original lignin content of the wood could be decreased as much as 80 percent. Recent work at the University of Maryland has shown that three strains of Polyporus versicolor were able to use lignin as the sole source of carbon (29) and that certain strains of Polyporus abietinus and of Poria subacida can be trained to do so by the use of an adaptation technique (10). Lignin-oxidizing enzymes were found to be present in mushroom spawn in which Agaricus campestris, the common edible mushroom, was grown (14).

BENEFICIAL EFFECTS OF WOODY RESIDUES ON SOILS

The benefits derived from the use of woody residues are due chiefly to their effects on the physical properties of soil (46, 47, 48), and not to their value as a fertilizer. Heavy clay soils are made more porous while

the moisture holding capacity of sandy soils is increased. Mulches usually reduce runoff and evaporation losses.

Preliminary investigations by Roberts and Stephenson (31) indicate that sawdust increases the effectiveness of inorganic fertilizers probably because of improved physical conditions of the soil.

Sawdust and wood shavings are efficient carriers of nitrogen and potash when used for the absorption of animal manures. The absorption efficiency for nitrogen may be increased by the addition of superphosphate (25). Dunn, Seiberlich, and Eppelsheimer (11) found that the addition of lignin caused a marked stimulation of growth of young potatoes treated with commercial fertilizers.

AVAILABILITY OF WOODY RESIDUES

The importance of the wood waste problem in the Northeastern States has already been mentioned. The following data, which were taken from figures published by the Forest Service as a result of a survey made in 1945 (52), indicate that the problem is not limited to New England.

Geographic distribution of wood wastes in the United States (millions of cubic feet) (52):

	Sawdust and shavings	Slabs, edgings, trimmings
New England	8.6	15.7
Middle Atlantic	15.7	31.5
Lake	11.4	17.2
Central	29.5	34.3
So. Atlantic	42.9	108.7
Southeast	200.2	117.3
West Gulf	116.7	37.2
Rocky Mt. (N)	25.7	32.9
Rocky Mt. (S)	5.2	10.0
Pacific N. W.	65.8	70.1
California	42.9	17.2
TOTAL	564.6	492.1

In fact it seems to be more acute in the Southern States and particularly in the Southeast where there is also a great need for soil organic matter.

If we include wood wastes from logging and manufacturing, a total of 4 billion cubic feet of unused material weighing approximately 66

million tons on a dry weight basis were available in 1944 (49).

Ligneous material, which is highly resistant to microbial decomposition is also available as a by-product of wood-sugar plants and paper pulping industries.

In many dairying regions, especially where grain residues are scarce, wood shavings and sawdust are finding increased usage as animal bedding.

The development of "wood hogs" or "chippers" makes an increasing amount of woody residues available to the farmer in a usable form.

On the other hand, research is continually seeking industrial uses of various kinds of crop wastes and residues (42). While such developments will, no doubt, lead to additional sources of revenue for the farmer and woodlot owner, it might be well to ask the question, "To what extent will the soil be robbed of a potential source of organic matter?"

SUMMARY

The literature review indicates that harmful effects on the growth of cultivated plants of sawdust and other woody materials when added to the soil are caused chiefly by a decrease in available nitrogen. This can be overcome to some extent by the use of commercial fertilizer, but the maintenance of a balanced supply of nitrate throughout the growing season by this means is difficult to attain.

Where woody materials are used along with adequate fertilization, or after proper composting or weathering, there is apparently little or no evidence to support the currently popular belief that toxic materials are released.

There is evidence, however, that materials are liberated during certain stages of decomposition of wheat straw, sweetclover, and other crop residues, and that these materials inhibit germination or the growth of seedlings.

Woody residues are very low in nitrogen, phosphorus, and potassium and consequently have practically no value as fertilizers. Sawdust and wood shavings, however, are being used extensively for the absorption of animal manures.

Available data indicate that woody residues decompose more slowly than wheat straw. There is some question as to the relative effects of these two materials on soil nitrates.

The chief benefit derived from the use of woody residues on soils is that of improving the physical properties of the soils.

Partially decomposed or weathered woody residues are better, from the viewpoint of nitrate depression, than the fresh materials. The composted or weathered material is also less likely to serve as an agent in the dissemination of certain plant pathogens.

Wood rotting organisms are widely distributed in nature and are ready to attack wood wherever it might be, provided an environment favorable to the growth of the microorganisms prevails.

Because of the availability of large quantities of wood wastes on the one hand and the need of the soil for organic matter on the other, there is a great need for experimental work in order to learn how to make the best use of this source of potential soil organic matter.

Experiments should be designed in such a manner as to evaluate the effects of kind of wood, physical condition (sawdust, shavings, chips) and state of weathering or decomposition when applied to different kinds of soil on the physical, chemical, and biological properties of the soils and on yield and quality of crops.

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